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MATHEMATICS TEACHERS' PROFESSIONAL DEVELOPMENT: A BIBLIOMETRIC ANALYSIS

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Abstract

Mathematics is one of the essential subjects for developing a national economy. It is the fourth element of the STEM acronym. Therefore, teachers' abilities need to be enhanced for the learning process to be effective. However, the majority of mathematics teachers in developing countries still have difficulty in obtaining professional development. The present study aims to identify the targets of mathematics teachers' professional development (MTPD) and examines its prominence in the literature over the past five years. It takes the form of a systematic review. The first objective is realized through the use of a qualitative, deductive, and thematic approach. The second objective is realized using the VOSviewer software tool (version 1.6.15.0). The 28 articles identified in the study were sourced from the Scopus database and published between 2016 and 2020. The results show that MTPD focuses on the implementation of technology, inquiry-based learning, problem-solving, and contextual (real-world) problems in the teaching and learning (T&L) process. The term was most often related to "mathematics," "professional development," "study," and "teacher." The results of the network visualization analysis of MTPD incorporate (a) professional development–teacher; (b) professional development–mathematics; (c) professional development–learning; and (d) professional development–mathematics teacher. The results of the study have implications for teachers trying to implement a T&L strategy that actively involves students in solving mathematical problems. It is recommended that future researchers identify MTPD in reference to (a) age; (b) gender; (c) the duration of teaching, (d) teaching location (urban and rural), and (e) the need to use more databases.

Keywords: *Mathematics, Teacher Professional Development, Teaching and Learning, Training*

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INTRODUCTION

Professional development (PD) involves acquiring more knowledge of the subject, understanding how to teach the subject, self-reflection, and beliefs. The PD of teachers is key to developing students' skills in the 21st century in all aspects. The main principle of PD is to emphasize a student-centered mathematical learning process, so learners can solve the various problems they face (Darragh & Radovic, 2019). According to Prast et al. (2018), it has a significant influence on the development of student achievement. Mathematics teachers who have undergone PD can have a positive impact on the learning process, the amount of teaching that takes place in the classroom, and teacher–student interaction (Gropen et al., 2017). During the implementation of mathematics teachers' professional development (MTPD), instructors are trained in the following: (a) communities of practice (asking questions, sharing ideas, discussing problems, and seeking advice); (b) induction and mentoring (observations, feedback, and modeling); (c) teacher socialization (interactions with peers, colleagues, and mentors); and (d) knowledge (instructional strategies, assessment, content knowledge, and classroom management (Surrette, 2020).

Several important points need to be considered by teachers to create an effective professional development program in mathematics learning: (a) content focus; (b) active learning; (c) collective participants; (d) fostering coherence; (e) duration; (f) research-based models; (g) data driven by students; (h) changes in teachers' beliefs and attitudes; and (i) teacher outcomes (Park et al., 2018). More than $18 billion is spent each year on PD to improve teaching quality (Martin et al., 2019).

However, the results of PD have not met expectations (Phelps et al., 2016). Many teachers have difficulty in planning mathematics lessons, especially technology-based ones (Getenet, 2019). Therefore, research is required that provides information on MTPD that could be practically useful. The present study therefore addresses the following questions:

1. What aspects of MTPD should be targeted in empirical research?
2. What are the most common terms of reference for MTPD in the empirical research?

METHODS

This section comprises: (a) the review process; (b) the database; (c) the key search; (d) the selection criteria; and (e) the data analysis.

The Review Process

The present study used a systematic review as its methodological basis. A systematic review can be strict, explicit, and responsible (Gough et al., 2017). It was used herein to synthesize the findings of previous articles, so that readers can become more informed (Boland et al., 2017). The review process, which applied inclusion and exclusion criteria, was carried out in line with the central research question. The next step was to search the appropriate database; the suitability of articles was determined by the title and the abstract. The VOSviewer software app (version 1.6.15.0) was used to identify the terms of relevance that most often appeared.

Database

Scopus, the largest database of peer-reviewed literature, was used to source the articles. They were then exported directly in the form of a "ris" file and analyzed with VOSviewer.

Key Search

The search string used for Scopus was as follows: TITLE-ABS-KEY (teacher AND professional AND development AND on AND mathematics) AND (LIMIT-TO (PUBSTAGE, "final")) AND (LIMIT-TO (PUBYEAR, 2020) OR LIMIT-TO (PUBYEAR, 2019) OR LIMIT-TO (PUBYEAR, 2018) OR LIMIT-TO (PUBYEAR, 2017) OR LIMIT-TO (PUBYEAR, 2016)) AND (LIMIT-TO (DOCTYPE, "ar")) AND (LIMIT-TO (SUBJAREA, "SOCI")) AND (LIMIT-TO (EXACT KEYWORD, "Professional Development") OR LIMIT-TO (EXACT KEYWORD, "Teaching") OR LIMIT-TO (EXACT KEYWORD, "Mathematics") OR LIMIT-TO (EXACT KEYWORD, "Students") OR LIMIT-TO (EXACT KEYWORD, "Education")) AND (LIMIT-TO (LANGUAGE, "English")) AND (LIMIT-TO (SRCTYPE, "j")).

Selection Criteria

The two types of selection criteria were inclusion and exclusion. Sources for inclusion were limited to: (a) publication between 2016 and 2020; (b) articles; (c) the social sciences; (d) the exact keywords of professional development or teaching or mathematics or student or education; (e) the English language; and (7) journals. The exclusion criteria that served to disqualify articles were: (a) mathematics and (b) explicitly on quantitative and qualitative methods (Figure 1).

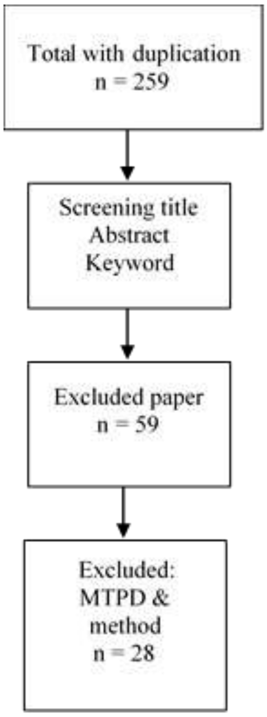

Figure 1. Inclusion and exclusion criteria for selection of article

Data Analysis

Article analysis was carried out based on the objectives of the study. The first objective was addressed using a systematic review and a qualitative, deductive, and thematic approach (Soroko & Dolczewski, 2020). Each article was analyzed in terms of (a) author; (b) sample; (c) teaching level; (d) setting; (e) PD item instructional strategy; (f) method/design; (g) duration; and (h) assessment. The second objective was addressed using the VOSviewer software tool (version 1.6.15.0).

RESULTS AND DISCUSSION

Mastery of technology is essential in all subjects. Its use is an inseparable component of T&L processes in the 21st century, especially in the context of the fourth industrial revolution. One of the most effective T&L methods in mathematics learning is technology-based learning (Maass & Engeln, 2019). A recent study by Getenet (2019) stressed the need for PD practitioners to focus on technology. This is necessary if teachers are to plan effective mathematics learning programs for their classes. Seven of the articles in the present study De Freitas and Spangenberg (2019); Getenet (2019); Gurevich et al. (2017); Havard et al. (2018); Huang et al. (2017); Kul (2018); Whittaker et al. (2020) supported this view (Table 1).

Table 1. Details of the studies included in the systematic literature review

Author	Professional Development Items
Darragh and Radovic (2019)	Collaborative problem-solving mathematics
Prast et al. (2018)	(a) Connect to daily teaching practice and focus on students' learning; (b) include models of preferred instructional method; (c) offer opportunities for active teacher learning; (d) stimulate collaboration and exchange between teachers; (e) offer multiple contexts, including classroom practice, for teacher learning; (f) be long-term, intensive, and sustainable
Surrette (2020)	Contextual elements of the ECTs' interactions
Park et al. (2016)	A. (a) content focus; (b) active learning; (c) fostering coherence; (d) duration; (e) collective participants; (f) teacher outcomes; (g) research-based models; (h) data-driven by students, and (i) changes in teachers' beliefs and attitudes B. Problem-solving abilities about rational numbers, and their teaching strategies using various representations
Martin et al. (2019)	Mathematics and literacy
Getenet (2019)	Use of technology in mathematics classrooms
Maass and Engeln (2019)	(a) Innovative teaching approach in mathematics and science education by connecting inquiry-based learning (IBL) to the world of work (WoW); (b) design tasks; (c) finding authentic contextual questions; and (d) developing their careers
De Freitas and Spangenberg (2019)	Integrating Information and Communication Technology (ICT)
Gurevich et al. (2017)	Technological tools (digital presentations or dynamic software, e.g., WhatsApp instant messaging application, GeoGebra, Wolfram platform, applets, Excel, and PowerPoint)
Havard et al. (2018)	(a) Instructional methods for teaching mathematics; (b) effective use of calculators in mathematics instruction; and (c) use of computers or other technology in mathematics instruction
Huang et al. (2017)	(a) Knowledge about mathematics teaching and learning and competence in mentoring and educational leadership and (b) knowledge about content, assessing student learning, and use of technology
Kul (2018)	Technology integrated (program designed using GeoGebra)
Whittaker et al. (2020)	Focus on online supports workshop-based support
McHugh et al. (2018)	Mathematics-infused science program (MiSP) curriculum inquiry-based activities
Polly et al. (2016)	Discovery/connections in their beliefs. Swan defined three levels of ideas: (a) transmission, which emphasises teacher-directed instruction; (b) discovery, which emphasizes student-led inquiry and explorations of mathematics concepts; and (c) connectionist
Saderholm et al. (2016)	Experienced inquiry-based, content-specific, focused grade-band sessions
Cerda et al. (2017)	Focus on problem-solving activities
De Araujo et al. (2017)	(a) Content knowledge in the context of their real-world experiences; (2) problem-centred mathematics
Palmér (2019)	Problem-solving questions and more concepts
Dawn (2018)	Open-ended, real-world problems
Andersson and Palm (2018)	Formative assessment (using assessment evidence for adapting teaching and learning activities to the students' learning needs)
Gasteiger and Benz (2018)	Knowledge and skills for mathematics education (counting, conceptual, and perceptual subitizing)
Joubert and Kenny (2018)	Personal, professional, and cultural/social
Mishal and Patkin (2016)	(a) Knowledge about other teachers; (b) teaching capabilities; (c) arithmetic capabilities; (d) geometry capabilities; (e) arithmetic teaching competences; and (f) geometry teaching competences
Polly et al. (2017)	Development project about an internet-based mathematics formative assessment tool and related pedagogies.
Schoen et al. (2019)	Teachers' knowledge of statistics and probability
Tian and Huang (2019)	Pedagogical content knowledge (PCK)
Tröbst et al. (2019)	Instruction on pedagogical content knowledge about fractions

Student engagement and teaching performance in mathematics can be improved through the use of GeoGebra, applets, PowerPoint, computerized algebra systems, Excel, the Wolfram platform, MathematiX, YouTube video lessons, and web resources (Getenet, 2019; Gurevich et al., 2017). Students prefer digital presentations during the teaching and learning (T&L) process (Gurevich et al., 2017). Additionally, teachers use email to communicate with students.

Researchers of PD have focused on the implementation of *inquiry-based learning* n = 4 articles, i.e., Maass and Engeln (2019); McHugh et al. (2018); Polly et al. (2016); Saderholm et al. (2016). The advantage of inquiry-based learning is that it helps teachers and students to: (a) engage; (b) explore; (c) explain; (d) elaborate; and (e) evaluate. The first level refers to the involvement of students, who play an active role in their learning and have their interest stimulated. The second level allows them to explore the topic they are studying. It provides an opportunity for them to understand relevant ideas and concepts. The third level enables them to convey to teachers and peers what it is they have been investigating. At the fourth level, students ask questions appropriate to the subject, and this advances the exploratory process. Finally, the evaluation of student findings is useful for assessing students' level of understanding of the relevant concepts and knowledge.

Another method employed in the implementation of mathematical learning that has been discussed by some researchers is the *problem-solving* approach n = 5 articles, i.e., Darragh and Radovic (2019); Cerda et al. (2017); De Araujo et al. (2017); Palmér (2019); Park et al. (2018). Problem-solving is one of the four skills that are explicitly referred to in the mathematics education curriculum (Cerda et al., 2017). Implementing problem-solving involves understanding the problem, devising a plan, carrying out the project, and checking and extending (Palmér, 2019). Teachers engage students in problem-solving and encourage them to find different solutions (Cerda et al., 2017). The final learning approach is based on *contextual (real-world problem) learning* n = 4 articles, i.e., Dawn (2018); De Araujo et al. (2017); Maass and Engeln (2019); Surrette (2020). This emphasizes solving mathematical problems as they relate to the real-world contexts in which the students find themselves (De Araujo et al., 2017). Contextual learning produces is most meaningful when learners are actively involved, for example when they are asking questions, discussing, explaining, and giving reasons as to how they have arrived at their findings.

The terms most associated with MTPD in the 28 articles analyzed were "mathematics" (occurrences = 38; relevance = 0.12), "professional development" (occurrences = 40; relevance = 0.18), "study" (occurrences = 40; relevance = 0.15), and "teacher" (occurrences = 46; relevance = 0.13). All four terms only appeared in articles published between 2017 and 2018 (Figure 2).

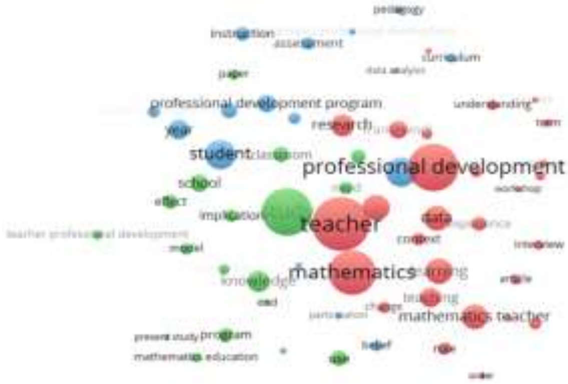

Figure 2. Mathematics teachers' personal development base on title, abstract, and keywords

Figure 3 displays the prevalence of relevant terms based on the years of publication. Figure 4 is a network visualization of MTPD terms.

Figure 3. Mathematics teachers' personal development base on years

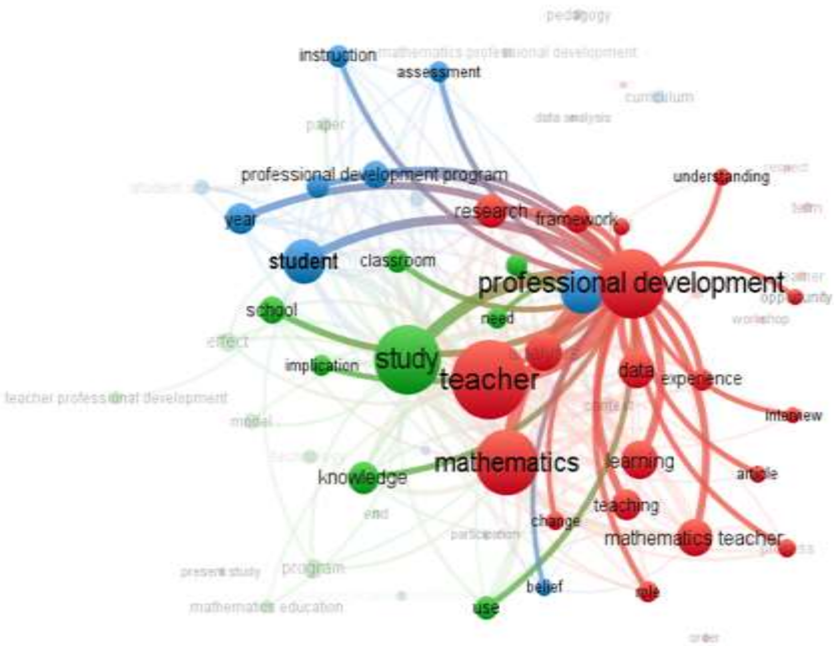

Figure 4. Network visualization of mathematics teachers' personal development terms

CONCLUSIONS

Mathematics Teachers' Personal Development is critical to student performance in schools. During the last five years (2016–2020), MTPD and its relationship with technology has been studied by a number of researchers particularly in the context of inquiry-based, problem-solving, and contextual (real-world problem) learning. Effective MTPD enables teachers to go away and actively involve students in the problem-solving process by adopting a facilitating role. Four terms relating to MTPD most often appeared in the title, abstract, and keyword in the articles that were included in the study: (a) mathematics; (b) professional development; (c) study; and (d) teacher. The most powerful network visualization of MTPD of the 28 articles analyzed displayed the following major categories: (a) professional development–teacher; (b) professional development–mathematics; (c) professional development–learning; and (d) professional development–mathematics teacher.

The limitations of the present study are as follows: (a) only 28 articles (sourced from the Scopus database) were analyzed; (b) the analysis (using VOSviewer) was limited to the title, abstract, and keyword of each article; and (c) only articles published between 2016 and 2020 were included. Future researchers could analyze the articles using the categories (a) age; (b) gender; (c) duration of teaching; and (d) teaching location (urban or rural), and access additional databases.

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